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Verification of Operational SIRS B Temperature Retrievals

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VERIFICATION OF OPERATIONAL SIRS B TEMPERATURE RETRIEVALS

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ABSTRACT. A verification procedure is applied to determine the accuracy of the Satellite Infrared Spectrometer (SIRS) B temperature retrievals by measuring their usefulness in the context of the National Meteorological Center (Suitland, Md.) operations. Three pressure levels are considered. It is shown that temperatures derived from satellite data for application at 200 mb are definitely useful while at 500 and 300 mb, under certain cloud conditions, the SIRS temperatures are moderately useful.

1. INTRODUCTION

Since the advent of the first experimental vertical sounding instruments, much attention has been focused on the Satellite Infrared Spectrometers (SIRS) A and B and the operational use of the temperature profiles retrieved from their radiation data. Our purpose here is to verify the SIRS B retrieved vertical temperature profiles provided operationally to the National Meteorological Center (NMC) from July 1970 to March 1972. The technique by which temperature profiles were obtained from measured radiances is described by Smith et al. (1972). For the present, it is sufficient to know that the temperature profiles were obtained by an iterative procedure wherein a guess temperature profile was perturbed to fit the measured radiances to within experimental error.

Before proceeding to a description of the verification technique, the reader should understand the fundamental tenet of this report. The verification must be carried out in dense data areas to have some standard against which to measure the accuracy of the SIRS data. Nevertheless, the verification technique is designed to determine the reliability of the temperature information provided by SIRS in areas both rich and sparse in conventional data. This point cannot be too strongly emphasized. Despite the fact that the verification is conducted in good data areas, the results are applicable to poor data areas as well.

To understand the verification technique, one must have some familiarity with analysis procedures at the NMC. For each synoptic analysis time (0000 and 1200 GMT), there are two principal objective analyses, one based on data collected up to 3.5 hr after synoptic time (operational analysis) and the other on data collected up to 10 hr after synoptic time (final analysis). Conventional data used in the operational analysis are reused, together with data received later, in the final analysis. SIRS data are used in both, but are processed somewhat independently in that different first-guess tempera-

ture profiles are used in the retrieval process. SIRS B temperature retrievals made for the operational analysis use a guess temperature profile derived from 12-hr forecast temperature fields predicted from the previous synoptic analysis. The temperature retrievals made for the final analysis use a guess temperature profile derived from the temperature fields of the operational analysis.

The verification is a comparison of two temperature differences -- the difference between SIRS-retrieved temperatures and the NMC (12-hr) forecast temperatures versus the difference (forecast error) between the "true" temperature (to be explained in the next section) and the NMC (12-hr) forecast. Moreover, because two nearly independent SIRS retrievals are made, two categories of comparisons can be made:

1. comparisons for retrievals based on forecast temperature profiles and

2. comparisons for retrievals based on concurrent analyzed profiles.

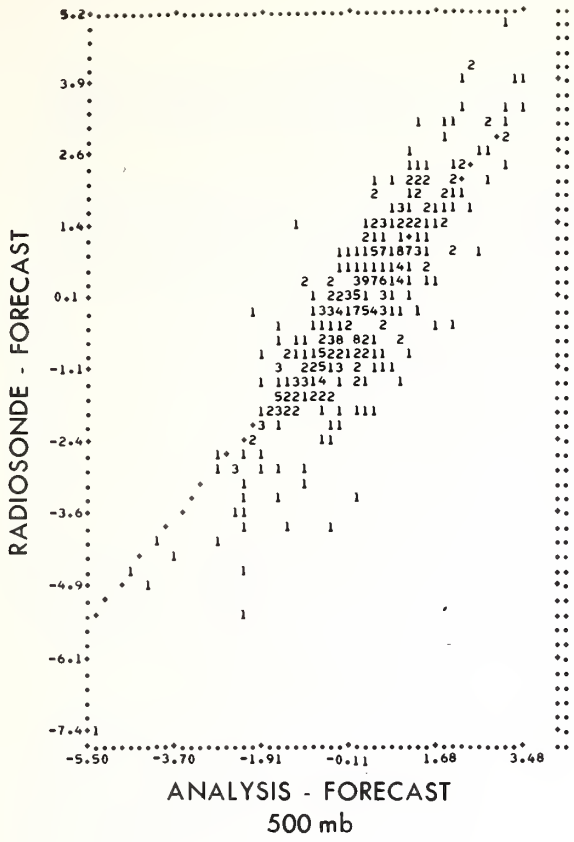
Comparison 1 indicates the effectiveness of the truly operational SIRS product while comparison 2 serves in effect as a limit to which comparison 1 can be expected to approach and also as a verification of the final SIRS retrieval data, which is the archived product.

Because we are evaluating the SIRS retrievals with respect to forecast error, we feel that the results of comparison 1 are applicable to sparse data areas even though they are computed in good data areas. The fact that short-term forecasts may be on the average more accurate in good data areas is of no consequence since we have been able to include cases where the forecast errors are relatively large. The only reason to suspect that SIRS modifications to the guess profiles might be different over sparse data areas is that terrestrial effects, which occur in the dense data areas, introduce some additional uncertainty in the retrieval procedure. For this reason, soundings over oceans might be slightly more consistent than those over land; but it is not presently possible to substantiate this hypothesis.

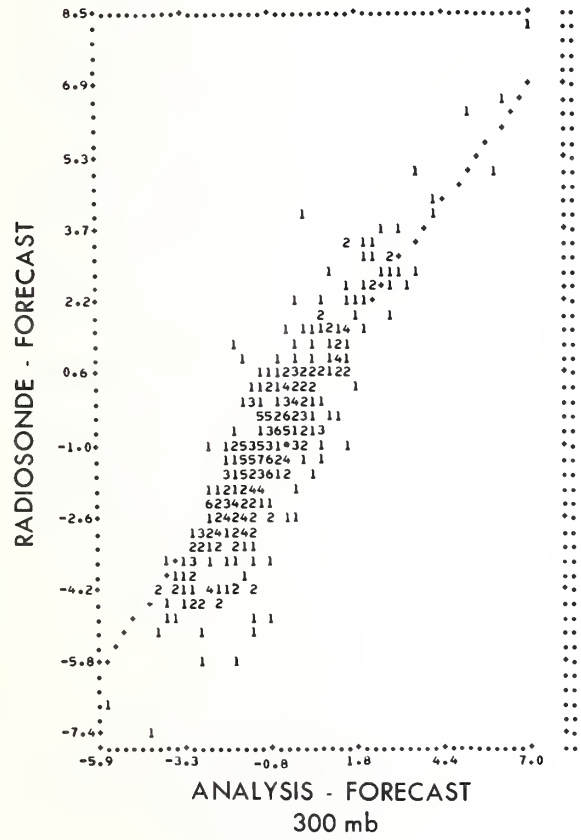
2. VERIFICATION METHOD

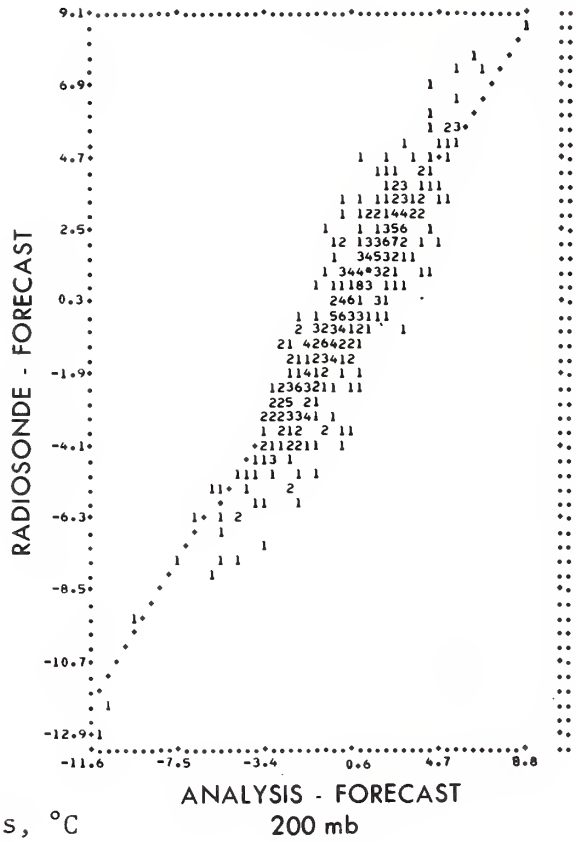
In the following evaluation, we shall be primarily concerned with two verification parameters, (1) the correlation coefficient (corr. coeff.) between the forecast error and the SIRS difference from the forecast and (2) the ratio of the standard deviation (std. dev.) of the forecast error to the root mean square (rms) error of the SIRS.

Determination of errors implies a knowledge of the truth. For the "truth," we used values obtained from the NMC objective analyses, but with a slight adjustment to compensate for smoothing accomplished by the objective analysis procedure. It is not our purpose here to discuss the relative merits of this smoothing but only to comment that, for the purpose of evaluating a point data source by reference to values interpolated in objectively analyzed fields, the smoothing implicit in the latter should be removed. Evidence of the smoothing can be seen in figure 1. This figure depicts for three levels the scatter of the difference from the 12-hr forecast indicated by radiosonde reports as compared to the differences indicated by colocated values interpolated in the operational objective analyses. The departure from a slope of 1 shown by the



	500 mb	300 mb	200 mb
Corr. Coeff.	0.87	0.89	0.92
rms	0.84°	1.02°	1.23°
Std. Dev. Analysis	1.32°	1.69°	2.64°
Std. Dev. Radiosonde	1.69°	2.15°	3.13°
Regression Slope	1.11	1.13	1.09
Regression Scatter	0.83°	0.98°	1.23°





Values, °C

Figure 1.--Radiosonde versus the objective analysis change to the 12-hr forecast. The line shown with the + symbols depicts 1:1 correspondence.

regression slopes in the figure indicate an average smoothing of the objective analysis procedure. The scatter of the points indicates a random error of either the radiosondes or the analysis.

Clearly, the smoothing bias should be accounted for in the verification of the SIRS retrievals. For an ensemble, this can be done by including the regression line slopes of figure 1 in the statistical comparisons as follows:

The expression for the rms difference between SIRS and the objective analysis values can be expressed after some manipulation as

$$\text{rms} = \left[\sigma_s^2 + \sigma_n^2 - 2r\sigma_s\sigma_n + \left(M_s - M_n\right)^2\right]^{1/2} \qquad (1)$$

where σ is the standard deviation of the SIRS sample (SIRS-forecast), σ_n is the standard deviation of the analysis sample (analysis - forecast), r is the correlation coefficient between the two samples, M_s is the mean deviation of the SIRS sample, and M_n is the mean deviation of the NMC sample.

All of the above parameters are computed directly from the samples. The final rms difference between the SIRS and the adjusted analysis values is computed from eq (1) modified such that the standard deviation of the analysis sample is multiplied by the appropriate regression line slope of figure 1. The adjusted rms value is our estimate of the SIRS error.

Note that, in boldly defining the term "SIRS error," we have ignored uncertainties engendered by radiosonde observational error, space, and time interpolations in the analyses. These uncertainties cannot be readily estimated, but we feel that they make a negligible contribution to the correlation coefficient or error ratio. For the interested reader, we have included a discussion of this assumption in the appendix where we show how one may properly include his estimates of uncertainty and so personally adjust the verification parameter reported here.

The error ratio (σ_n/rms, adjusted by the slope factor) is a straightforward estimate of the utility of the SIRS. A ratio greater than unity signifies that the forecast error is greater than error contained in the SIRS estimates. In such a case, the SIRS can be said to be useful in correcting the forecast. It is difficult, however, to define a degree of utility from the magnitude of error ratio. For this reason, we are also presenting the correlation coefficient that we hope will aid the reader's interpretation of the results. A discussion of the relationship between the error ratio and the correlation coefficient is included in the appendix.

In the following section, the results of this report are summarized in graphs presenting together the correlation coefficient and the error ratio. This allows the viewer to approximate the correlation coefficient corresponding to the point where the SIRS sample begins to improve on the forecast (i.e., an error ratio equal to unity) and thus to better judge how much the SIRS values improve on the forecast. The method of scaling the two parameters is discussed in the appendix.

3. RESULTS

The results presented here are from six samples taken during the period July 20, 1970, through March 21, 1971. The data used were collected up to 6 hr prior to analysis time in areas with reasonably dense conventional data coverage. Retrievals affected by high clouds (cloud pressure <550 mb and cloud amount >10 %), as defined by the retrieval procedure, were not accepted. SIRS and forecast errors as described above were correlated for both heights and temperatures at the 500-, 300-, and 200-mb levels; and the thickness and mean temperatures for the 500- to 300-mb and 500- to 200-mb layers. However, only the results of temperature verifications are presented in this report. Constant pressure height results are discussed elsewhere by Hayden (1971).

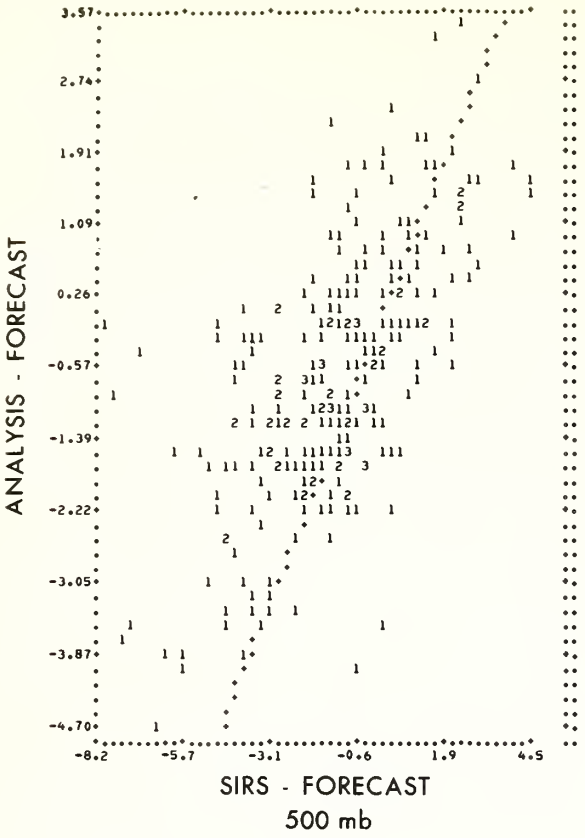
Three cloud condition categories are used to break down each of the samples and are defined as: (1) clear, (2) lower clouds below 700 mb in height, and (3) higher clouds above 700 mb, but excluding the above-defined high cloud category. These are as inferred by the SIRS retrieval model for the final SIRS retrieval. Table 1 presents the sample size and time period for each of the six samples along with the number in each of the cloud categories.

The summarized results are presented with limited discussion as it is beyond the scope of this report to explore all causes behind the trends or relative comparisons of the verification of the various parameters. We are treating a research instrument that was used operationally; manifold changes were made in the retrieval processing during the time period we are here discussing. For those interested in some detail, the basic scatter diagrams of temperature differences (uncorrected by slope factor) for the SIRS B data processed for the operational analyses and a complete set of the statistics for both operational and final retrievals are shown in the appendix.

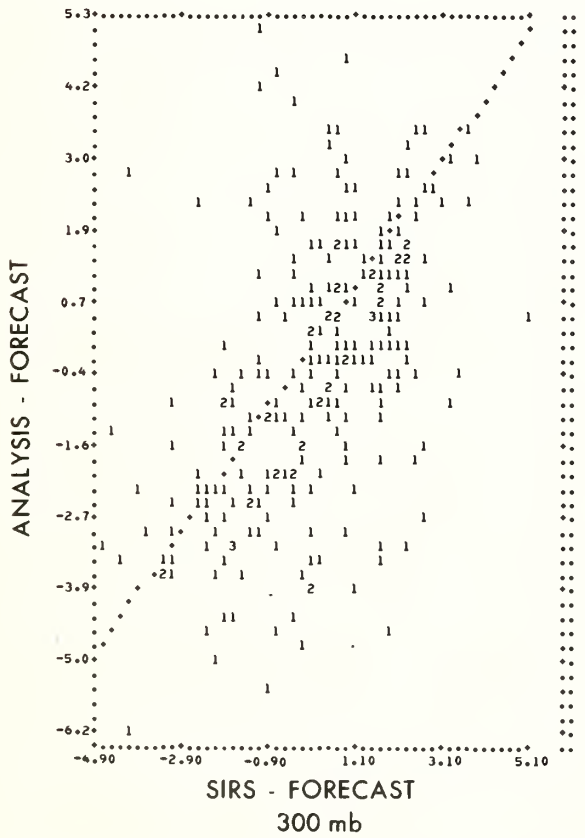
The scatter diagrams in figures 2 and 3 are illustrative of the results obtained from the study. These distributions are from the March sample for all cloud conditions combined and for only the cloud-free conditions. For the 500- and 300-mb diagrams, the regression slopes of <1 indicate that the SIRS retrievals overspecified the analyzed changes to the forecast tempera-

Table 1.--Period and size of each sample with the number in each cloud category

Sample	Period	Total size	Clear	Lower	Higher
1	July 20-Sept. 24, 1970	180	34	45	101
2	Sept. 25-Nov. 8	226	26	56	144
3	Dec. 10-Jan. 4, 1971	218	43	91	84
4	Jan. 9-Jan. 29	243	31	69	143
5	Feb. 2-Feb. 22	274	29	84	161
6	Mar. 1-Mar. 20	258	19	70	169



	500 mb	300 mb	200 mb
Corr. Coeff.	0.63	0.50	0.82
rms	1.91°	2.05°	2.43°
Std. Dev. Analysis	1.45°	2.18°	4.13°
Std. Dev. SIRS	2.23°	1.79°	2.91°
Regression Slope	0.41	0.61	1.16
Regression Scatter	1.12°	1.88°	2.38°



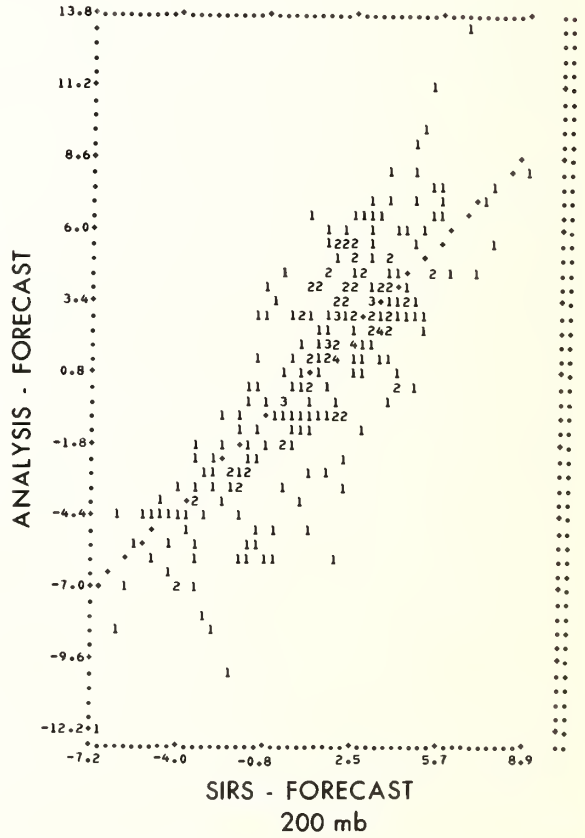
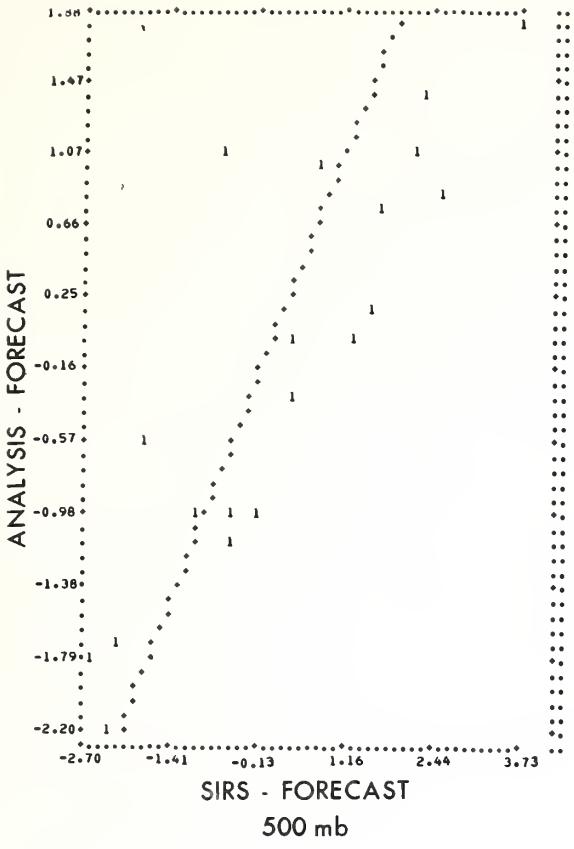
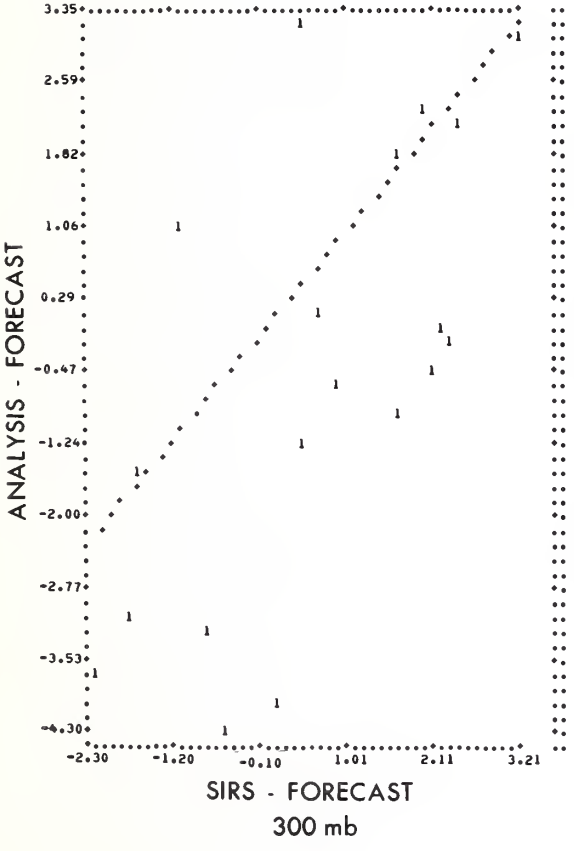


Figure 2.--SIRS versus the analysis change to the 12-hr forecast for all cloud conditions, March 1971 sample



	500 mb	300 mb	200 mb
Corr. Coeff.	0.87	0.66	0.85
rms	1.00°	2.03°	1.94°
Std. Dev. Analysis	1.15°	2.32°	3.30°
Std. Dev. SIRS	1.77°	1.57°	2.65°
Regression Slope	0.56	0.97	1.06
Regression Scatter	0.57°	1.75°	1.73°



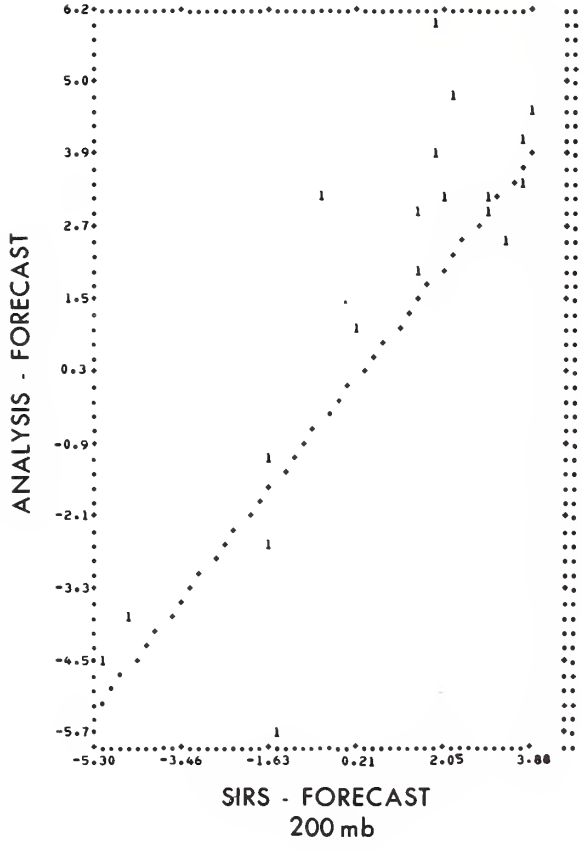


Figure 3.--Same as figure 2 except this is for clear cases

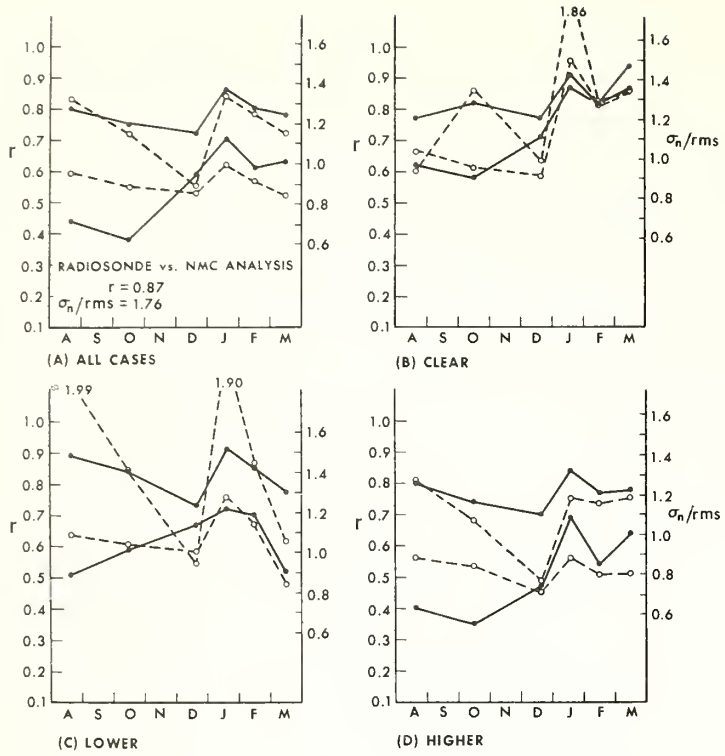


Figure 4.--Correlation coefficient for operational 500-mb temperature retrievals (lower solid line) and for final retrievals (upper solid line); error ratio for operational retrievals (lower dashed line) and for final retrievals (upper dashed line)

tures. At 200 mb, the slope of >1 indicates underspecification of analyzed temperature change. Consideration of the radiosonde-analysis slope factor (i.e., multiplying the regression slopes by the slope factor) makes the overspecification look more reasonable at 500 and 300 mb, although it increases the underspecification at 200 mb.

The graphs of correlation coefficient and error ratio for the three levels and all cloud categories are shown in figures 4, 5, and 6. Two sets of statistics are presented in each graph, corresponding to the operational and final retrievals. The latter are always on top since they are always "better" from the advantage of a more accurate first guess. In many cases, the statistics for the final retrievals are off the graph scale, which was designed to emphasize the results of the operational retrievals.

Let us consider first the operational retrievals. Note that, for the total samples of the operational retrievals, the results are superior at 200 mb (compare figs. 4A, 5A, and 6A). Substantial improvement over forecast temperatures is demonstrated by the SIRS retrievals. It is also encouraging to note that, at 500 and 300 mb (figs. 4A and 5A), the operational retrievals are comparable or tend to add some information to the forecast temperature values, particularly in the last three or four samples at 500 mb. Clearly, however, cloud contamination is reducing the effectiveness of the SIRS at these levels. The slightly better results at 500 mb compared to those at 300 mb is somewhat puzzling but may be due to the lack of sufficient vertical resolution in the area of the tropopause because of the absence of the 692 cm^{-1} channel radiance observations in the retrievals (Smith et al. 1972). For the three levels, the remaining portions of figures 4, 5, and 6 display the samples broken down according to cloud conditions. Several interesting quirks are evident, emphasizing the difficulties caused by cloud contaminations.

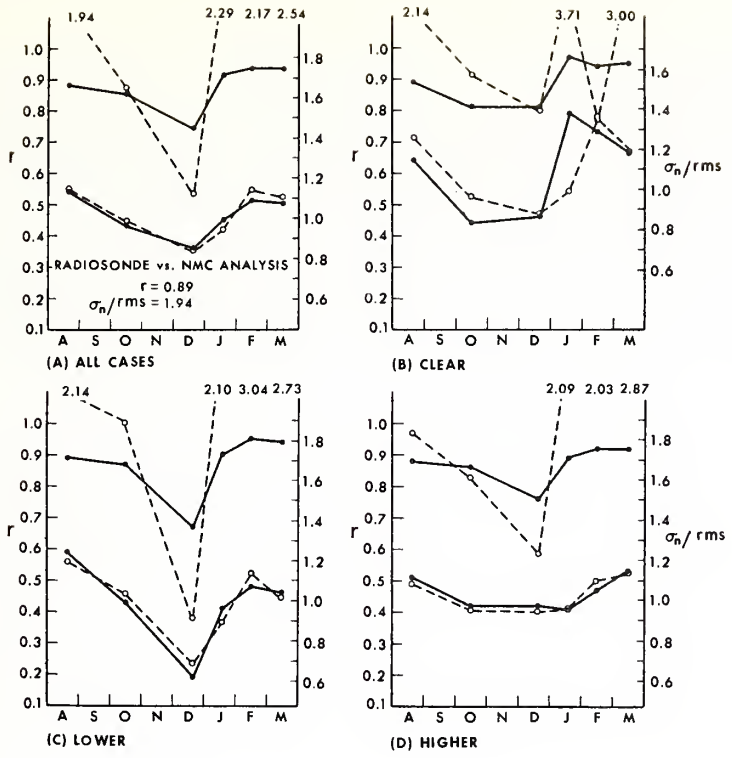


Figure 5.--Same as figure 4 except this is for operational 300-mb temperature retrievals

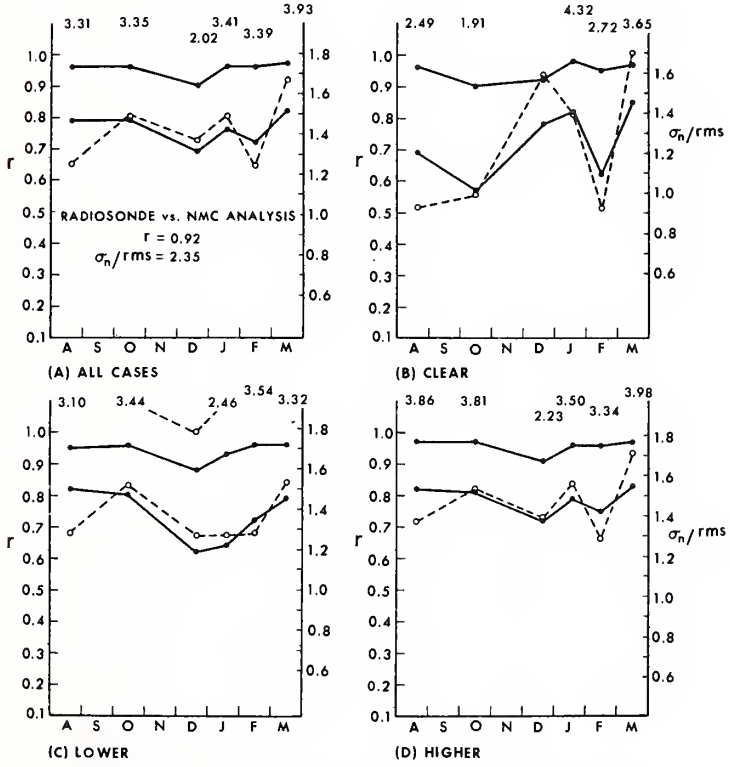


Figure 6.--Same as figure 4 except this is for operational 200-mb temperature retrievals

Two points especially require some clarification. (1) While at 500 and 300 mb the operational retrievals obtained from clear-sky measurements are generally better than the retrievals obtained from cloud-contaminated measurements, there are periods at 200 mb when the reverse is true. (2) Consistently at 200 mb and occasionally at the other levels, the operational retrievals obtained with higher cloud conditions are superior to those obtained under lower cloud conditions. Both these results are unrealistic. On the average, the no-cloud solutions should always be best; and the solutions should deteriorate as higher clouds occur and more opaque channels are influenced.

The first of the above apparent paradoxes can be explained if we hold to the hypothesis that, when the error ratio is near or <1, it is questionable whether we are obtaining any information from the SIRS measurements beyond what is available in the forecast temperature. In figures 4-6, when the statistics distinctly indicate an improvement over the forecast temperatures for the clear cases, the clear solutions are indeed better or at least as good as the cloudy solutions. Only when the statistics are marginal do the cloudy solutions occasionally become superior. This implies that many clear cases are not truly clear, and cloud contamination has not been properly accounted for.

The second paradox, that the higher cloud solutions at 200 mb tend to appear better than the lower cloud solutions, is also explicable. Within the retrieval model, the number of radiance measurements that are used in the inversion to obtain a temperature profile is a function of the cloud conditions determined. If any clouds are indicated, the most transparent carbon-dioxide channel is not used in the inversion. If at least 10 % cloud at or above 700 mb is indicated, the two most transparent channels are not used. In other words, with the lower cloud cases of figures 4-6, an additional measurement has been used. At 200 mb, we may be actually degrading the retrieval because the added channel has not been properly corrected for cloud; and a good retrieval can be made at this level without the two more transparent channels. At 500 and 300 mb, the more transparent channels are necessary to the retrieval; and the cloud corrections, while not right, are sometimes better than nothing. At these lower levels, the paradox exists only when the statistics indicate the retrievals are comparable to or have more error than the forecast temperatures (i.e., when we have no added information in the measurements).

The final retrievals (upper curves in figs. 4-6) show substantially better results. The statistics improve with height, and all points show that at least some correction has been made to the forecast temperature field. This is to be expected since the retrievals were initiated with a guess considerably better than the forecast temperatures. The relatively poor results in the December sample at 500 and 300 mb, and to a slight extent at 200 mb, may be attributed to stratospheric warming events that could not be retrieved accurately at high levels (due to erroneous guess temperature profile), with the resultant errors propagating into the tropospheric levels.

Error ratios and correlation coefficients computed for the radiosonde samples of figure 1 are shown at the bottoms of figures 4A, 5A, and 6A. It is interesting to note that, for all samples at 200 mb and in some of the cloud breakdowns in the later samples at 500 and 300 mb, the final SIRS data are more consistent with the "truth" (as defined) than are the radiosonde data.

Table 2.--Average rms errors for mean temperatures (in deg.) of the specified layers and for individual levels

	Mean temperature rms			Temperature rms		
	850-500 mb	850-300 mb	850-200 mb	500 mb	300 mb	200 mb
All cases	1.8	1.5	1.1	1.6	2.0	2.6
Clear	1.6	1.3	1.1	1.2	1.8	2.6
Lower	1.5	1.2	0.9	1.3	2.0	2.4
Higher	2.1	1.7	1.2	1.9	2.0	2.7

The improvement of the statistics of the final retrievals over those of the operational retrievals demonstrates a bias of the SIRS retrievals to their initial guess temperature profiles. This is entirely to be expected since both the "minimum information" method of inversion and the method of cloud correction result in a bias toward the guess.

Previous discussions of SIRS accuracy (Wark 1971) indicated expected and observed accuracies for rms temperature errors at both individual levels and in layers. For comparative purposes, rms errors (averaged for all the samples) are presented in table 2 for each of the three levels individually and for a layer from 850 mb to each level. The mean temperature rms errors were computed from height rms errors for the last five samples in which the 850 mb NMC height was used as the reference height to hydrostatically build up the SIRS heights. As indicated by Wark, the mean errors decrease with increasing layer thickness for all cloud conditions. Puzzling is the tendency for the lower cloud category to yield results better than the clear category; but this may again be due to the inclusion of an additional channel, improperly corrected, in the latter retrievals. The individual level rms errors in table 2 increase with height since the upper two levels are in the vicinity of the tropopause where errors have been consistently greater according to previous papers (Wark 1971 and Smith et al. 1972). Consequently, for layers thicker than the 850- to 500-mb layer, the mean rms errors become less than the individual level errors at the top of the layer. The magnitude of the mean errors in table 2 are somewhat larger than those suggested by Wark, but we should again blame cloud contamination.

Finally, we would like to reassert our contention that, for operational retrievals, these results apply equally in data-poor as well as data-rich areas. As partial substantiation to this claim, we should mention that we have applied the verification techniques to samples with larger forecast errors simply by excluding those cases with small observed error. In this way, we have to some extent simulated poorer forecasts that might be expected in data-sparse regions. Results for the restricted samples are almost indistinguishable from those for the total samples.

4. SUMMARY AND CONCLUSIONS

The NMC forecast is used as a basis for obtaining the SIRS B operational retrievals and as a first guess for the succeeding constant-pressure analyses. The theme of the verification scheme presented here is simply to measure the ability of the SIRS retrieved data to add information to the NMC analysis first guess.

At 200 mb, the results are quite encouraging, showing a generally good ability to add significant information to the guess temperature profiles, except for an indication of some sensitivity in SIRS-deduced clear conditions where the lack of proper corrections to the two most transparent carbon-dioxide channels (wave nos. 734 and 750) evidently was detrimental to the retrievals. The retrieved temperatures at 500 mb show consistent ability to properly correct guess profile errors in the clear and lower cloud cases. The higher cloud cases display a slight amount of additional information only in the later samples. At 300 mb, somewhat less information is added to the guess temperatures than at the other two levels, though the clear cases give generally good and occasionally very good results. The cloud-contaminated cases tend to yield a modest correction of guess temperature errors, but the results are mixed. That is, in some samples, lower cloud conditions give better results than the higher (as in the 500-mb situation); in others, higher cloud retrievals are better (as at 200 mb).

The results rather clearly indicate that a primary difficulty in obtaining accurate and useful retrievals lies in the cloud problem, both because of improperly correcting observed radiances to account for cloud contamination and because the loss of information in the retrievals when strongly cloud affected SIRS channels are not used. This difficulty should be greatly alleviated with future, higher resolution sounders that will probe between the clouds.

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APPENDIX

In this section, we shall address three of the more technical details not covered in the main body of the text; and we shall present statistics for operational and final retrievals and scatter diagrams for cloud categories of operational retrievals.

A. Errors in Verification Standard

A clearly defined bias in the objective analyses of temperature that we used as the verification standard has been accounted for. Less well defined errors introduced by radiosonde measurement error or space and time interpolation have been ignored. We shall indicate here how the latter could be included in the correlation coefficient and error ratio.

A correlation coefficient that includes additional uncertainty in the objective analysis can be computed from the sample correlations as

$$\hat{r} = r\left(\frac{\sigma_n^2}{\sigma_n^2 - \varepsilon^2}\right)^{1/2}\left(\frac{1 - C_{s\varepsilon}}{C_{sn}}\right) \qquad (2)$$

where ε^2 is the variance of the additional uncertainty; $C_{s\varepsilon}$ is the covariance of the uncertainty and the SIRS sample; and C_{sn} is the covariance of the SIRS and analysis samples. Other variables retain their previous definitions. It is apparent from eq (2) that random errors would absolutely cause improvement only in the absence of a positive correlation between the SIRS indicated changes and the uncertainty. It is not likely that correlation exists from a bias in radiosonde measurements, but there could well be a correlation with the errors introduced by space and time interpolation of the objective analyses.

Similar terms are added to the error ratio. Including the uncertainty, the ratio is given by

$$\left(\frac{\sigma_n^2 - \varepsilon^2}{\mathrm{rms}^2 - \varepsilon^2 + C_{s\varepsilon}}\right)^{1/2} . \qquad (3)$$

The error ratio will be improved (increased) in only those samples where SIRS is already shown to be beneficial (i.e., those cases where the ratio is greater than unity) and then only if the SIRS indicated changes and the uncertainty are poorly correlated.

In presenting our results,we have chosen to ignore the additional uncertainty terms. We believe them to have a very small effect on the magnitude of the correlation coefficient and on the question of whether the error ratio is greater or less than unity.

B. Relationship Between Error Ratio and Correlation Coefficient

If we assume that the mean forecast error is zero (as can be shown empirically), the correlation coefficient can be expressed by

$$r = \frac{\sigma_s^{\ell} + \sigma_n^2 - \mathrm{rms}^2 + M_s^2}{2\sigma_s\sigma_n} \quad . \tag{4}$$

If we make the approximation that the mean SIRS error is zero, the correlation coefficient can be written in terms of ratios

$$r = \frac{R_s}{2} + \frac{1}{2R_s}\left(1 - \frac{1}{R^2}\right) \tag{5}$$

where R_s is the ratio of the standard deviations given by the SIRS and analysis indicated changes to the initial guess and R is our defined error ratio. In general, the error ratio increases as the correlation coefficient increases, but there is no direct correspondence. For example, if the error ratio is held at unity, the correlation coefficient can vary as the standard deviation of the SIRS changes varies. The error ratio and correlation coefficient give equivalent information only when the standard deviations of SIRS and analysis changes are of the same magnitude.

C. Technique of Scaling Error Ratio Versus Correlation Coefficient

To plot the correlation coefficient and the error ratio on the same graph, we used the following scaling for figures 4, 5, and 6. For all graphs, the same linear distance represents a given increment in the error ratio or in the correlation coefficient. The increment in both cases is the standard deviation of all correlation coefficients or error ratios obtained from the operational retrievals of individual months, levels, or cloud categories. This ensures that, on the graphs, the correlation coefficient and the error ratio are scaled approximately equivalently. On individual graphs representing a single level and cloud condition, the scale of the error is moved such that the average operational correlation coefficient (from the 6 mo of data) lies opposite the average operational error ratio.

Sample 1.--July 20-September 24, 1970

Cloud conditions	Corr. coeff.	rms	Std. dev. analysis	Std. dev. SIRS	Mean error‡	Regression Slope	Regression Scatter
200 mb All cases	0.79*	2.46°	3.00°	1.83°	-1.53°	1.29	1.85°
	.96†	0.99	3.00	3.25	-0.36	0.89	0.84
Clear	.69	3.17	2.82	1.28	-2.34	1.52	2.04
	.96	1.18	2.82	2.80	-0.88	0.97	0.78
Lower	.82	2.07	2.56	1.83	-1.43	1.14	1.48
	.95	0.87	2.56	2.85	-0.11	0.86	0.76
Higher	.82	2.34	3.22	1.96	-1.30	1.35	1.82
	.97	0.97	3.22	3.53	-0.30	0.88	0.82
300 mb All cases	0.54	1.32°	1.46°	1.24°	-0.17°	.64	1.23°
	.88	0.83	1.46	1.68	- .25	.77	0.69
Clear	.64	1.22	1.50	1.20	- .31	.79	1.15
	.89	0.76	1.50	1.65	- .12	.81	0.68
Lower	.59	1.19	1.39	1.11	.25	.74	1.13
	.89	0.72	1.39	1.55	- .07	.80	0.64
Higher	.51	1.41	1.47	1.31	- .32	.58	1.26
	.88	0.89	1.47	1.73	- .37	.75	0.69
500 mb All cases	0.44	1.23°	1.10°	1.20°	- .13°	.40	.99°
	.80	0.93	1.10	1.51	.17	.58	.65
Clear	.62	.89	0.86	0.86	.48	.62	.68
	.77	1.02	.86	1.09	.74	.60	.55
Lower	.51	1.16	1.22	1.08	- .20	.57	1.05
	.89	0.67	1.22	1.44	.17	.75	0.55
Higher	.40	1.35	1.11	1.28	- .30	.35	1.02
	.80	0.99	1.11	1.61	- .02	.55	0.67

*Upper number refers to operational retrievals.
†Lower number refers to final retrievals.
‡Mean error = $M_s - M_n$. (See text.)

Sample 2.--September 25-November 8, 1970

Cloud conditions	Corr. coeff.	rms	Std. dev. analysis	Std. dev. SIRS	Mean error‡	Regression Slope	Regression Scatter
200 mb All cases	0.79*	2.49°	3.79°	2.17°	-0.44°	1.38	2.31°
	.96†	1.18	3.79	4.03	- .43	0.90	1.03
Clear	.57	2.63	2.51	1.39	-1.63	1.03	2.06
	.90	1.39	2.51	2.55	-0.80	0.89	1.10
Lower	.80	2.08	3.27	1.91	- .18	1.38	1.94
	.96	1.07	3.27	3.61	- .21	0.87	0.93
Higher	.81	2.61	4.09	2.37	- .33	1.39	2.42
	.97	1.19	4.09	4.35	- .45	0.91	1.03
300 mb All cases	.43	1.80°	1.68°	1.51°	- .59°	.48	1.51°
	.85	1.14	1.68	2.06	- .36	.69	0.87
Clear	.44	1.71	1.57	1.06	- .89	.65	1.41
	.81	1.09	1.57	1.72	- .36	.73	0.92
Lower	.43	1.53	1.51	1.29	- .27	.50	1.36
	.87	0.90	1.51	1.81	.05	.72	0.75
Higher	.42	1.91	1.72	1.61	- .65	.45	1.56
	.86	1.22	1.72	2.15	- .51	.69	0.88
500 mb All cases	.38	1.42°	1.18°	1.35°	.10°	.33	1.09°
	.75	1.15	1.18	1.72	- .01	.51	0.79
Clear	.58	1.23	1.11	0.87	.80	.74	.90
	.82	0.89	1.11	1.21	.56	.75	.63
Lower	.59	1.11	1.09	1.10	.49	.58	.88
	.84	0.87	1.09	1.50	.24	.61	.59
Higher	.35	1.55	1.22	1.45	- .18	.29	1.15
	.74	1.28	1.22	1.86	- .21	.49	0.83

*Upper number refers to operational retrievals.
†Lower number refers to final retrievals.
‡Mean error = $M_s - M_n$. (See text.)

Sample 3.--December 10-January 4, 1971

Cloud conditions	Corr. coeff.	rms	Std. dev. analysis	Std. dev. SIRS	Mean error‡	Regression Slope	Regression Scatter
200 mb All cases	0.69*	2.57°	3.52°	2.56°	-0.34°	0.95	2.54°
	.90†	1.90	3.52	4.04	.69	.78	1.53
Clear	.78	2.14	3.38	2.75	- .37	.96	2.11
	.92	1.77	3.38	4.08	.67	.76	1.32
Lower	.62	2.71	3.43	2.46	- .05	.87	2.69
	.88	2.04	3.43	3.82	.99	.79	1.60
Higher	.72	2.61	3.66	2.45	- .64	1.08	2.53
	.91	1.80	3.66	4.18	.39	0.79	1.53
300 mb All cases	.36	2.24°	1.73°	1.93°	.85°	.33	1.61°
	.74	1.73	1.73	2.44	.56	.53	1.16
Clear	.46	2.00	1.62	1.70	1.01	.44	1.43
	.81	1.30	1.62	2.00	0.55	.65	0.95
Lower	.19	2.44	1.55	1.93	.97	.15	1.52
	.67	1.91	1.55	2.26	.88	.46	1.16
Higher	.42	2.13	1.88	1.90	.65	.42	1.71
	.76	1.71	1.88	2.62	.21	.55	1.22
500 mb All cases	.59	1.68°	1.30°	2.06°	- .19°	.37	1.05°
	.72	1.66	1.30	2.27	- .42	.41	0.90
Clear	.71	1.43	1.16	1.87	.52	.44	.82
	.77	1.33	1.16	2.01	.04	.45	.73
Lower	.67	1.42	1.31	1.91	- .14	.46	.97
	.73	1.55	1.31	2.15	- .40	.44	.90
Higher	.47	2.01	1.30	2.15	- .60	.28	1.15
	.70	1.91	1.30	2.43	- .69	.38	0.93

*Upper number refers to operational retrievals.
†Lower number refers to final retrievals.
‡Mean error = $M_s - M_n$. (See text.)

Sample 4.--January 9-January 29, 1971

Cloud conditions	Corr. coeff.	rms	Std. dev. analysis	Std. dev. SIRS	Mean error‡	Regression Slope	Regression Scatter
200 mb All cases	0.76*	2.41°	3.58°	2.55°	-0.52°	1.06	2.35°
	.96†	1.20	3.58	3.93	.28	0.87	1.05
Clear	.82	2.32	3.08	2.82	-1.47	.90	1.76
	.98	0.89	3.08	3.57	0.28	.84	0.64
Lower	.64	2.19	2.76	2.10	- .47	.84	2.11
	.93	1.25	2.76	3.09	.43	.83	1.04
Higher	.79	2.53	3.98	2.65	- .33	1.18	2.46
	.96	1.23	3.98	4.30	.21	0.89	1.11
300 mb All cases	.45	2.11°	1.89°	1.69°	.97°	.51	1.63°
	.91	0.96	1.89	2.23	.06	.77	0.80
Clear	.79	2.11	1.92	1.60	1.75	.95	1.18
	.97	0.70	1.92	2.35	-0.07	.79	0.49
Lower	.41	2.25	1.89	1.50	1.25	.51	1.73
	.90	0.99	1.89	2.18	0.32	.78	0.81
Higher	.41	2.04	1.83	1.71	.67	.44	1.67
	.89	0.99	1.83	2.14	- .04	.76	0.84
500 mb All cases	.70	1.68°	1.51°	2.22°	- .57°	.48	1.07°
	.86	1.30	1.51	2.29	- .34	.57	0.77
Clear	.87	1.23	1.61	2.22	.47	.63	.79
	.91	1.03	1.61	2.19	.23	.66	.68
Lower	.72	1.15	1.36	1.61	- .11	.61	.95
	.91	0.85	1.36	1.82	- .21	.68	.57
Higher	.69	1.96	1.56	2.32	-1.02	.47	1.12
	.84	1.51	1.56	2.46	-0.52	.53	0.84

*Upper number refers to operational retrievals.
†Lower number refers to final retrievals.
‡Mean error = $M_s - M_n$. (See text.)

Sample 5.--February 2-22, 1971

Cloud conditions	Corr. coeff.	rms	Std. dev. analysis	Std. dev. SIRS	Mean error‡	Regression Slope	Regression Scatter
200 mb All cases	0.72*	3.32°	4.08°	2.75°	-1.77°	1.07	2.81°
	.96†	1.29	4.08	4.32	-0.42	0.91	1.15
Clear	.62	3.68	3.20	2.48	-2.63	.79	2.52
	.95	1.27	3.20	3.58	-0.63	.85	0.96
Lower	.72	2.89	3.66	2.34	-1.35	1.13	2.54
	.96	1.06	3.66	3.82	-0.16	0.92	1.00
Higher	.75	3.46	4.39	2.91	-1.83	1.13	2.92
	.96	1.40	4.39	4.65	-0.51	0.91	1.23
300 mb All cases	.51	2.16°	2.41°	1.78°	.28°	.69	2.07°
	.93	1.31	2.41	3.02	- .59	.74	0.88
Clear	.73	1.60	2.14	1.82	.62	.86	1.45
	.94	1.95	2.14	3.39	-1.14	.59	0.76
Lower	.48	2.15	2.40	1.54	0.22	.75	2.11
	.95	0.88	2.40	2.69	- .27	.85	0.74
Higher	.47	2.25	2.40	1.83	.25	.61	2.12
	.92	1.36	2.40	2.98	- .66	.74	0.91
500 mb All cases	.61	1.81°	1.50°	2.19°	- .47°	.42	1.20°
	.80	1.36	1.50	2.22	.02	.54	0.90
Clear	.82	1.21	1.37	1.83	.58	.61	.78
	.82	1.22	1.37	2.04	.08	.55	.79
Lower	.70	1.34	1.41	1.88	.08	.53	1.00
	.85	1.12	1.41	2.03	.02	.59	0.75
Higher	.54	2.09	1.54	2.18	- .94	.38	1.29
	.77	1.48	1.54	2.31	.00	.51	0.97

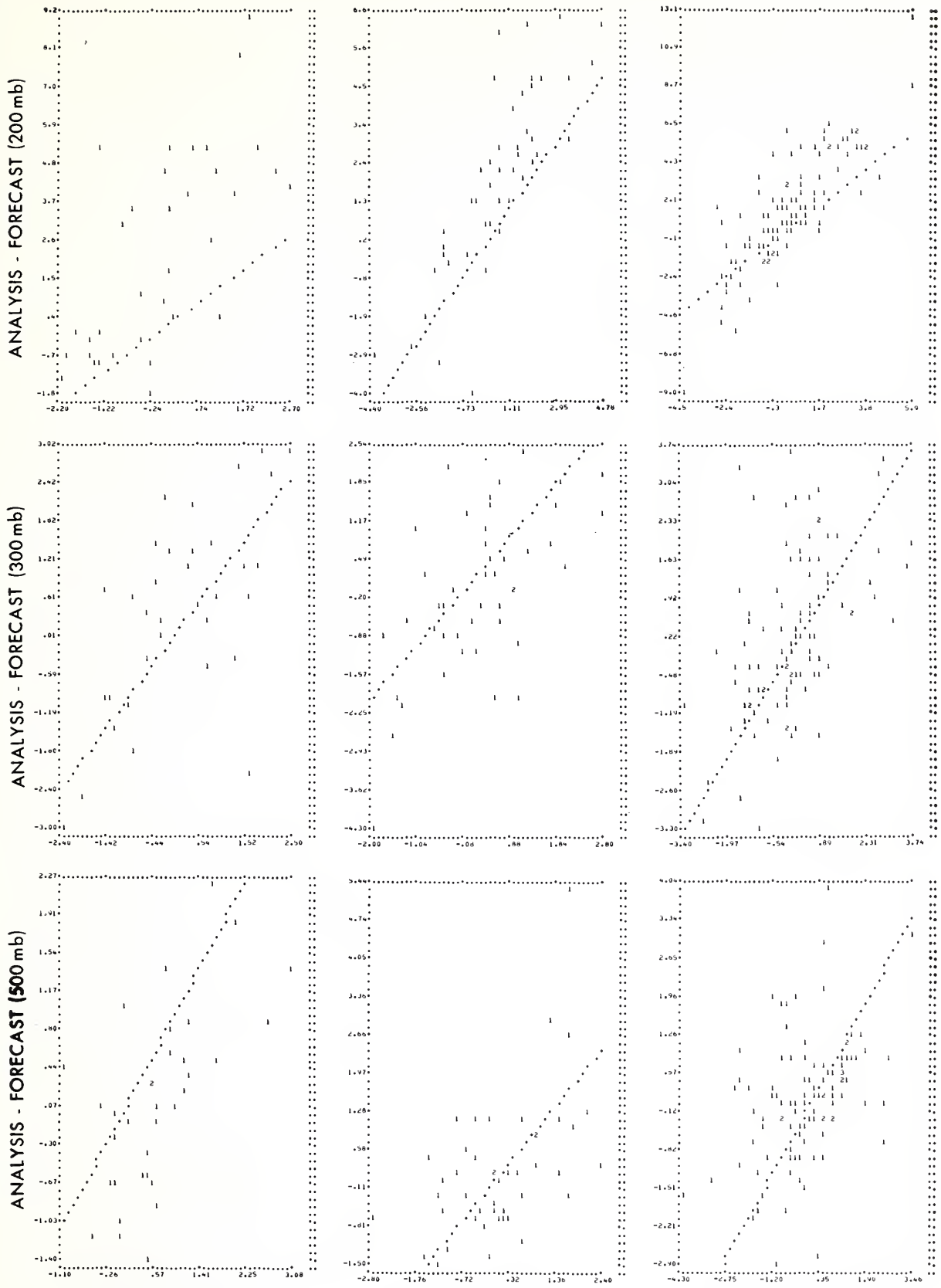
*Upper number refers to operational retrievals.
†Lower number refers to final retrievals.
‡Mean error = $M_s - M_n$. (See text.)

Sample 6.--March 1-20, 1971

Cloud conditions	Corr. coeff.	rms	Std. dev. analysis	Std. dev. SIRS	Mean error‡	Regression Slope	Regression Scatter
200 mb All cases	0.82*	2.43°	4.13°	2.91°	-0.20°	1.16	2.38°
	.97†	1.25	4.13	4.55	.29	0.88	1.08
Clear	.85	1.94	3.30	2.65	- .86	1.06	1.73
	.97	1.06	3.30	3.89	.21	0.83	0.79
Lower	.79	2.60	4.06	2.68	- .56	1.20	2.48
	.96	1.27	4.06	4.42	.46	0.89	1.07
Higher	.83	2.41	4.20	3.02	.03	1.15	2.37
	.97	1.26	4.20	4.61	.23	0.88	1.10
300 mb All cases	.50	2.05°	2.18°	1.79°	.41°	0.61	1.88°
	.93	0.99	2.18	2.61	.14	.78	0.79
Clear	.66	2.03	2.32	1.57	1.03	.97	1.75
	.95	0.89	2.32	2.71	0.21	.82	0.71
Lower	.46	2.24	2.19	1.65	.88	.60	1.95
	.94	0.92	2.19	2.63	.12	.79	0.72
Higher	.53	1.97	2.15	1.85	.14	.61	1.83
	.92	1.03	2.15	2.59	.14	.77	0.82
500 mb All cases	.63	1.91°	1.45°	2.23°	- .82°	.41	1.12°
	.78	1.41	1.45	2.14	- .40	.53	0.90
Clear	.87	1.00	1.15	1.77	.28	.56	.57
	.94	1.05	1.15	2.03	.17	.53	.40
Lower	.52	1.69	1.31	1.67	- .79	.41	1.12
	.77	1.38	1.31	1.84	- .71	.55	0.84
Higher	.64	2.06	1.52	2.39	- .96	.41	1.16
	.78	1.46	1.52	2.23	- .33	.53	0.96

*Upper number refers to operational retrievals.
†Lower number refers to final retrievals.
‡Mean error = $M_s - M_n$. (See text.)

Sample 1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ANALYSIS - FORECAST (300 mb)
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LOWER CLOUD
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HIGHER CLOUD

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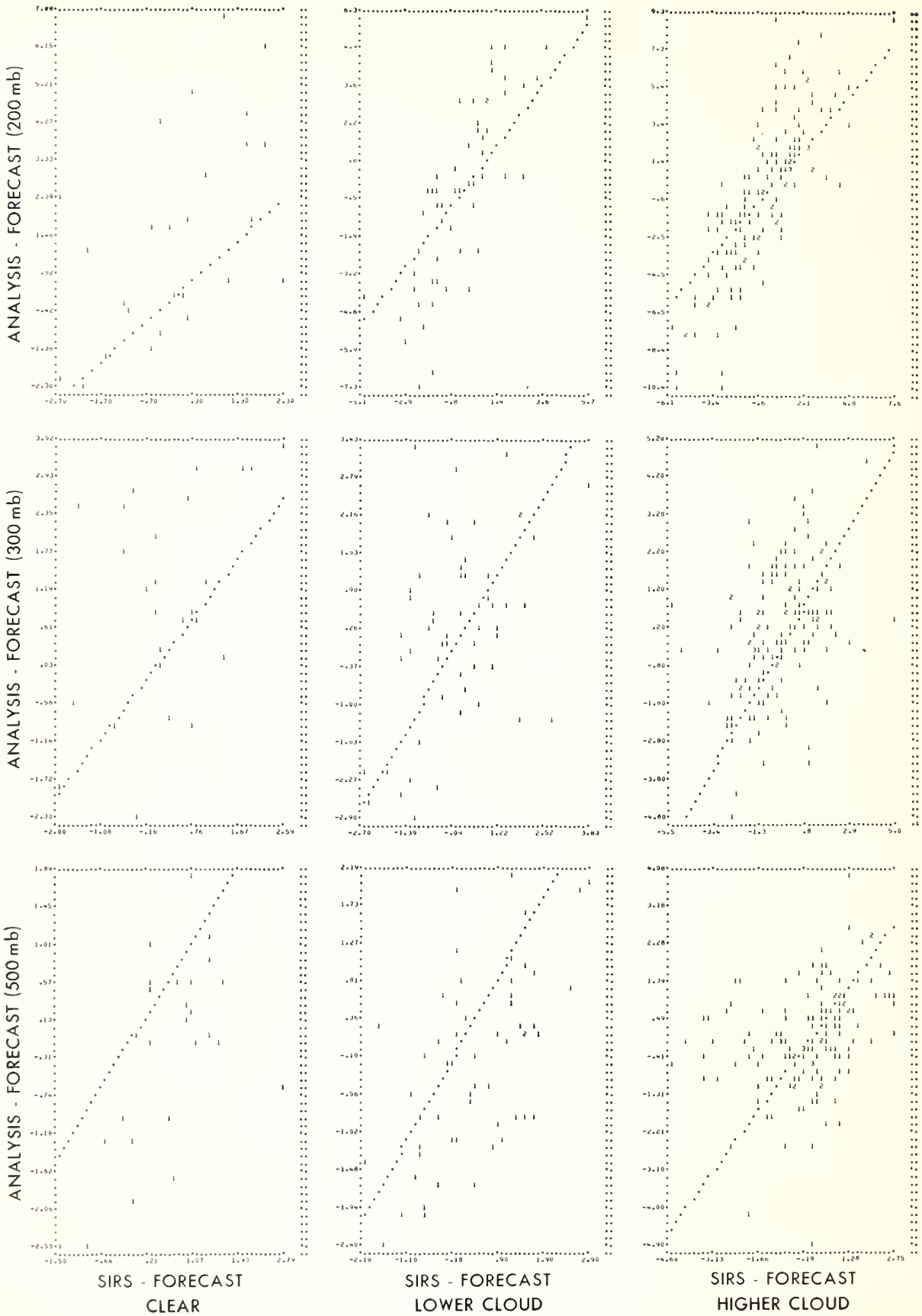
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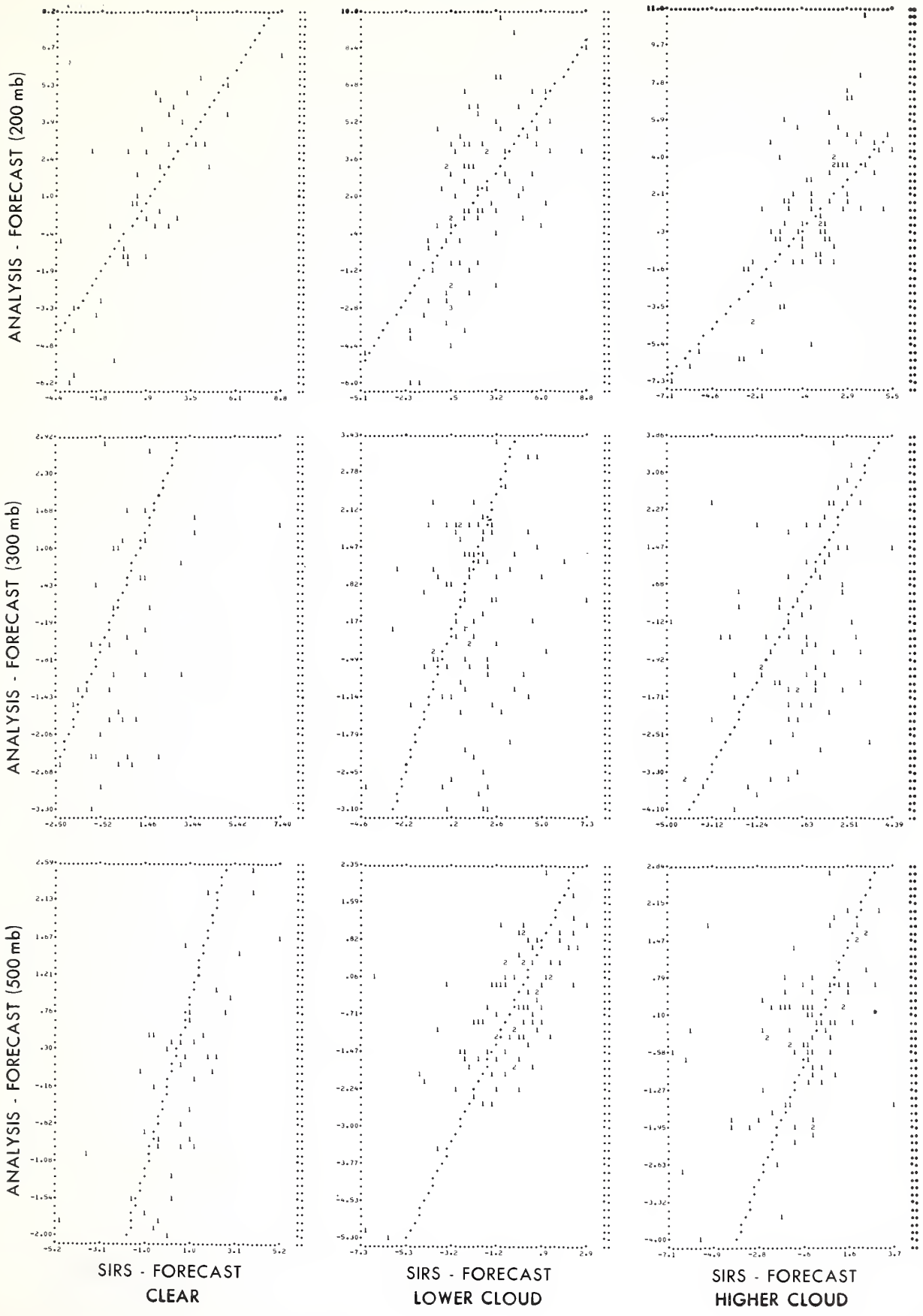
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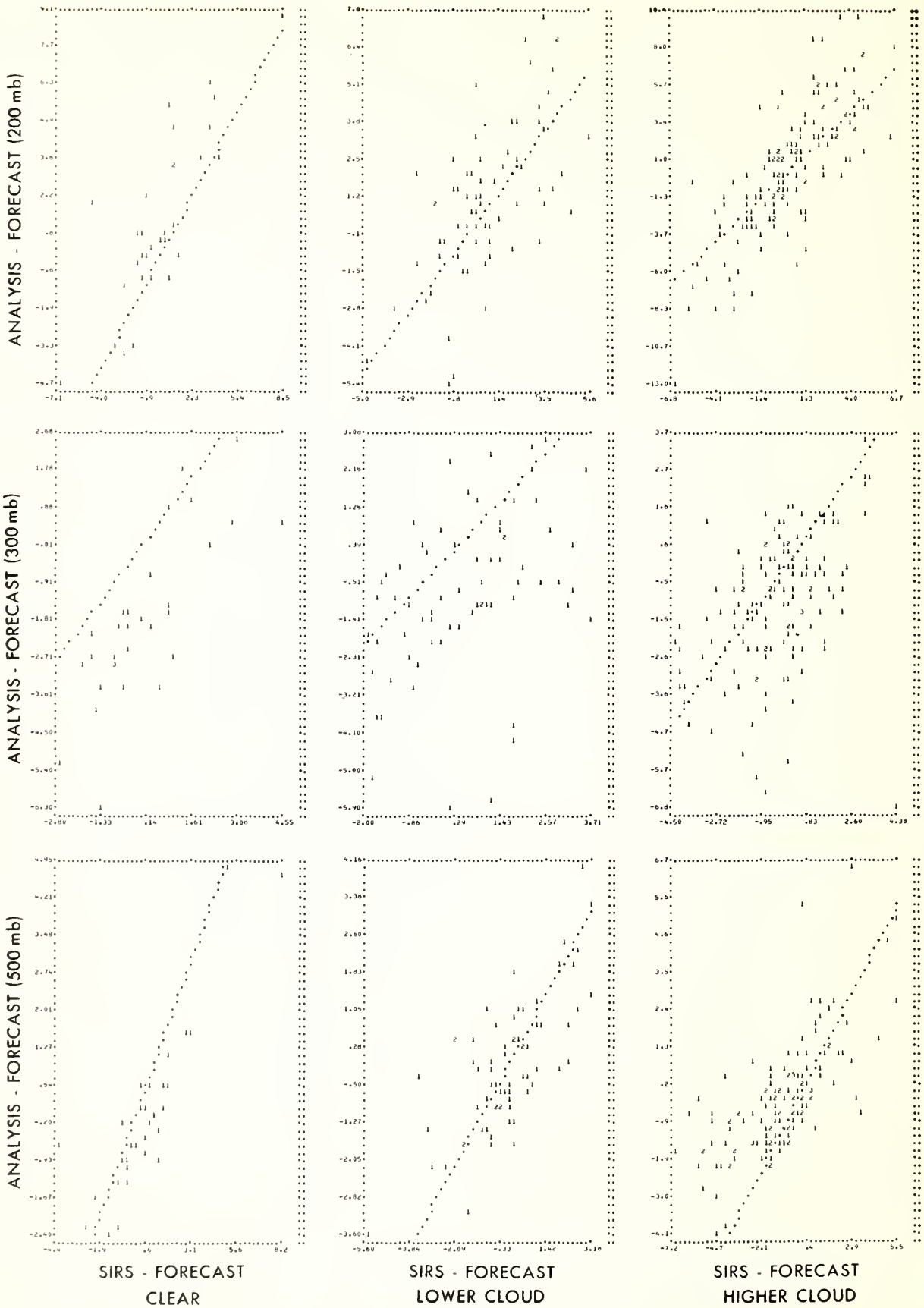
Sample 4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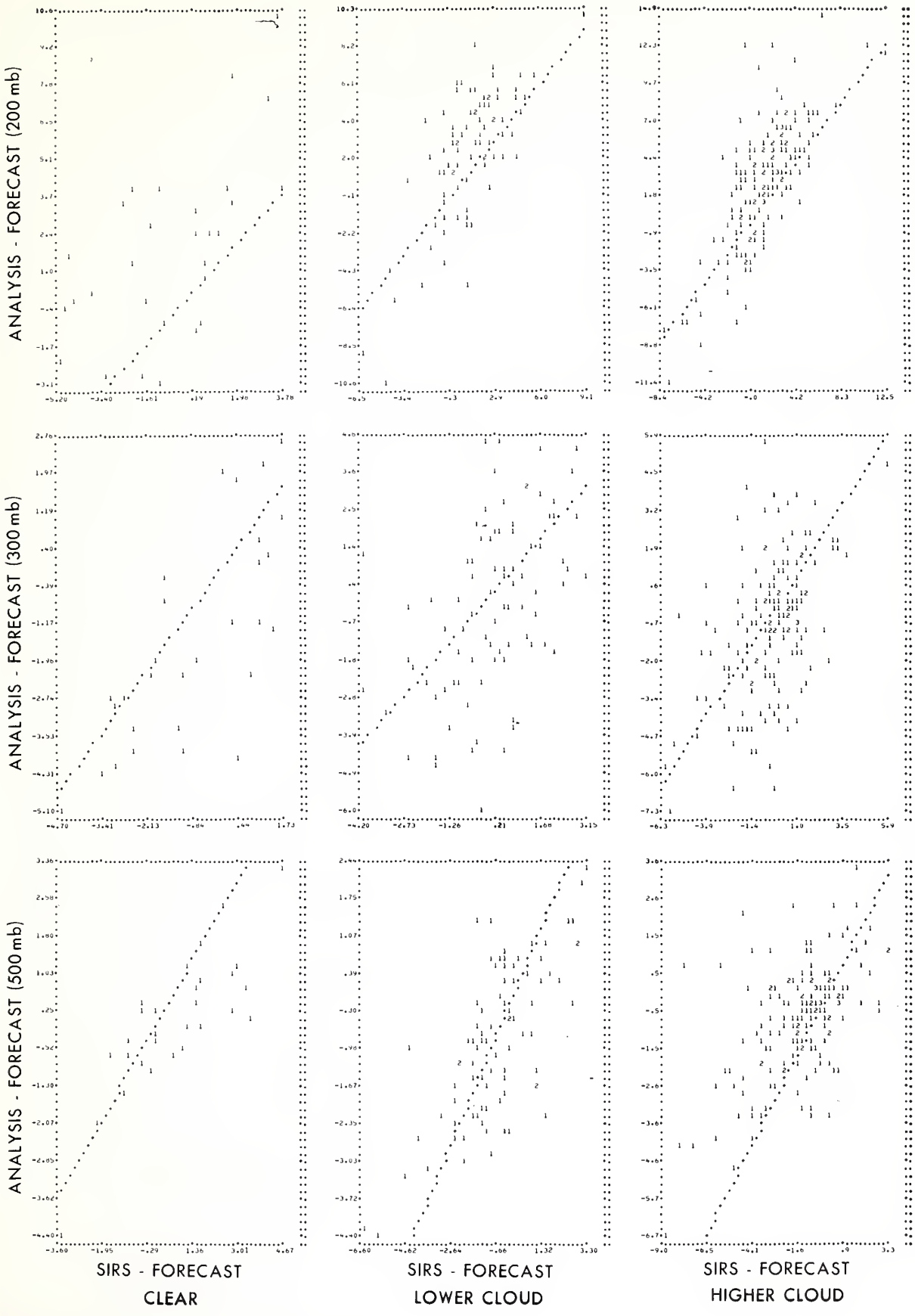
SIRS - FORECAST
HIGHER CLOUD

Sample 5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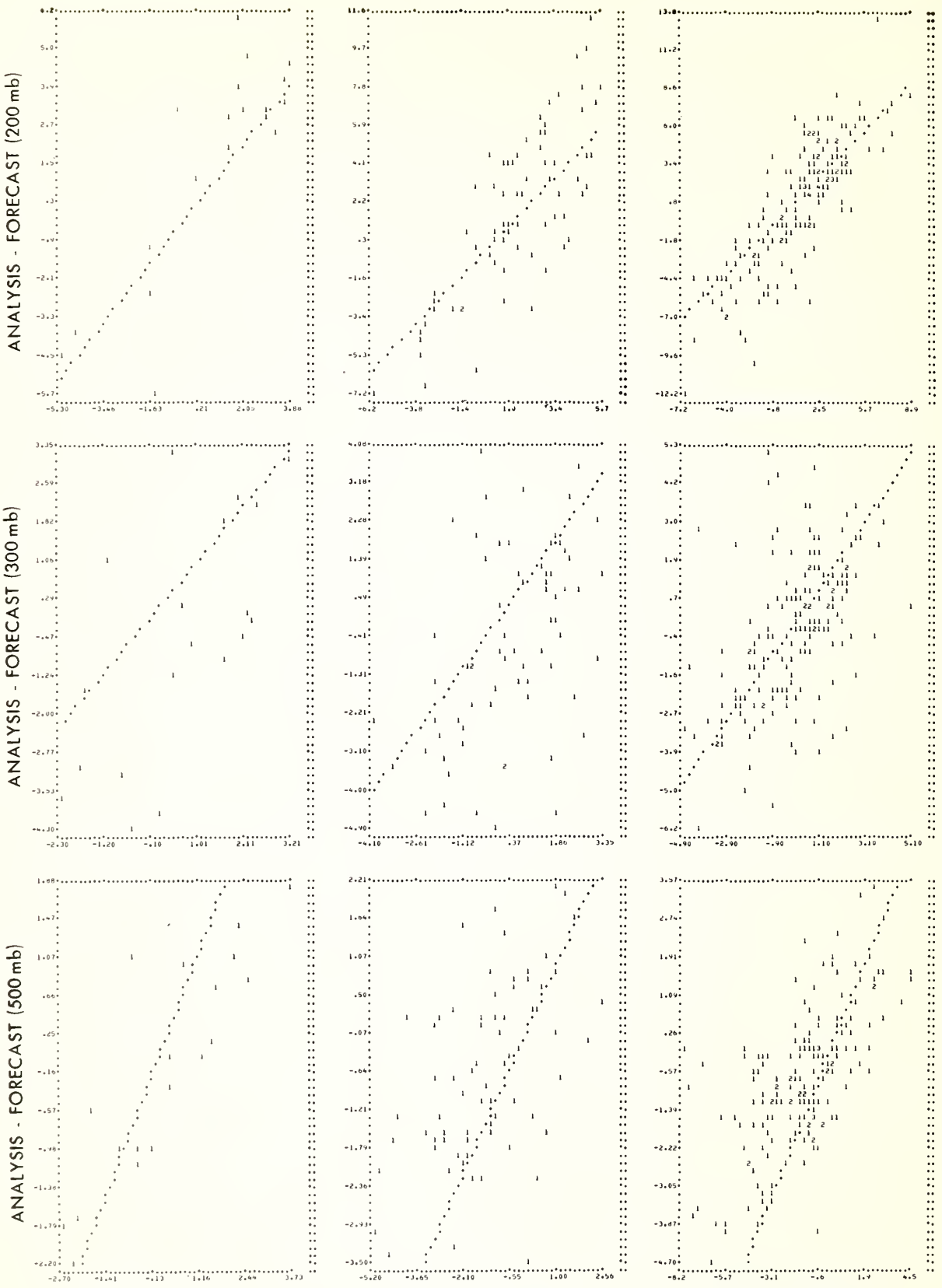
LOWER CLOUD
SIRS - FORECAST
HIGHER CLOUD

Sample 6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SIRS - FORECAST
CLEAR
SIRS - FORECAST
LOWER CLOUD
SIRS - FORECAST
HIGHER CLOUD

(Continued from inside front cover)

NESC 51 Application of Meteorological Satellite Data in Analysis and Forecasting. Ralph K. Anderson, Jerome P. Ashman, Fred Bittner, Golden R. Farr, Edward W. Ferguson, Vincent J. Oliver, and Arthur H. Smith, September 1969. Price $1.75 (AD-697-033) · Supplement price $0.65 (AD-740-017)

NESC 52 Data Reduction Processes for Spinning Flat-Plate Satellite-Borne Radiometers. Torrence H. MacDonald, July 1970. Price $0.50 (COM-71-00132)

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NESC 56 Time-Longitude Sections of Tropical Cloudiness (December 1966-November 1967). J. M. Wallace, July 1970. Price $0.50 (COM-71-00131)

NOAA Technical Reports

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